

## Snapshots from the decade of the brain

### Brainy mind

Richard Gregory

We have all been struck by the spooky question: Is your sensation of green like my green? For how can we compare sensations—or *qualia*, as philosophers call them—of colours, tastes, or sounds? Our green *qualia* may be different (and in cases such as colour anomalies must be different), though we all call grass green and assume we all see the same.

#### Where do sensations come from?

The primary question is whether the brain receives or makes sensations. When we look at grass: is the sensation of green picked up by the eyes, from light reflected from the grass, or is the sensation, the *qualia* of green, created in our brains? It is now as certain as anything—as Isaac Newton appreciated three centuries ago—that light itself has no colour. Light evokes colour in suitable eyes and brains, which is very different. And violins have no sounds without ears and brains to create sound *qualia*. Recently the brain scientist Semir Zeki located colour creating cells in the brain (in the visual area of the striate cortex V4).

One can imagine a bunch of interacting robots getting on fine without any awareness of *qualia*; but surely they wouldn't spend hours looking at pictures, or listening to Beethoven. This is just how behaviourist psychologists a few years ago described us—as lacking consciousness, or *qualia* of red or pain or the sound of violins. Why an audience without music *qualia* would sit through a symphony was hardly questioned. Now, psychology has abandoned the behaviourism of J B Watson and B F Skinner, who tried to make psychology seem more scientific and less whimsical by denying consciousness. The situation is reversed so that physicists, especially Roger Penrose, are asking how the physical world can have consciousness. And the brain is very generally seen as a physical system obeying physical laws. Consciousness is a hot scientific topic. Philosophers such as Daniel Dennett and Paul and Patricia Churchland, as well Francis Crick, discuss from the basis of detailed knowledge of neurophysiology and brain anatomy how the mind can be brainy.

It remains mysterious how physical stimuli affecting the physical brain give us, and presumably at least the higher animals, the consciousness of *qualia*. If *qualia* affect the nervous system, how can chemistry and physiology give adequate explanations of behaviour and of how the brain works? Yet why should consciousness have evolved if it is useless?

The key notion of cognitive psychology since the collapse of behaviourism is that we build brain descriptions of the world of objects, which give perception and intelligent behaviour. Perceptions are not regarded as internal pictures or sounds, but rather as language-like descriptions coded, we suppose, by brain structures of what may be out there. We carry in our heads predictive hypotheses of the external world of objects and of ourselves.<sup>1 2</sup> These brain-based hypotheses of

#### Summary points

Sensations of consciousness—*qualia*—are created by the brain

*Qualia* are psychologically projected into the external world of objects

Perceptions are predictive hypotheses, based on knowledge stored from the past

As perceptions may be 90% memory, how is the present moment distinguished from memory and anticipation?

*Qualia* may be evoked by afferent sensory stimuli to avoid confusion with the past and future by flagging the present moment

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perception are our most immediate reality. But they entail many stages of physiological signalling and complicated cognitive computing, so experience is but indirectly related to external reality.

From patterns of stimulation at the eyes and ears and the other organs of senses, including touch, we project sensations of consciousness into the external world. Although this is a startling thought, the experience of projecting afferent reality from the eyes is familiar in visual after-images. Try looking at a bright light, then at a surface such as wall. You see the pattern that is photographed on the retina from the flash as outside the eye, as being on the wall. The more distant the surface the larger it appears, though of course the retinal photograph is unchanged. This startling notion that perception is projecting brain-hypotheses outwards into the physical world—endowing the world with colour and sound and meaning—has surprising implications.

#### Some truths from illusions

Paradoxically, such truths of perception are revealed most clearly through illusions. Quite simple figures or objects can be ambiguous, spontaneously changing into other orientations or other objects, although there are no changes of the images in the eyes. This is evidence of changes of the brain's hypotheses of what is out there. Just as for clinical or scientific hypotheses, there may be many interpretations of the available evidence, and background knowledge is important, though it is not always appropriate. An example of the misleading power of inappropriate knowledge is a hollow mask (fig 1).

Changes of brain hypotheses change the meaning of perceptions and maybe even sensations. This was realised in the nineteenth century by the Austrian



**Fig 1** Hollow mask. The hollow inside of the mask seems to be a normal face with a nose sticking out. For the positions and shapes of the eyes and mouth and so on, call up the brain's hypothesis of a face, which past knowledge says is sticking out. This is how the hollow mask appears, though we know that the perception is false. This shows the modularity of brain and mind. Perceptual and conceptual hypotheses may disagree when brain communication is lacking<sup>3</sup>

physicist Ernst Mach.<sup>4</sup> Figure 2 shows an ambiguous corner which flips in and out in depth. When the flipping corner is in, the grey region may look considerably lighter than when it sticks out. It looks lighter when seen as a shadow than as a mark on the surface, for shadows are normally minimised, as they are not objects for behaviour. (This little experiment works well with a shadow on a folded menu at a boring dinner!)

Listen to a tape recording of an audience clapping. In the kitchen it sounds like bacon frying. In the garden on a dull day it sounds like rain. It is interesting to repeat words or musical phrases on a tape loop: after several repetitions they seem to change into other words or phrases. Though seeing and hearing and touch seem simple and direct, they are not. They are fallible inferences based on knowledge and assumptions which may not be appropriate to the situation.

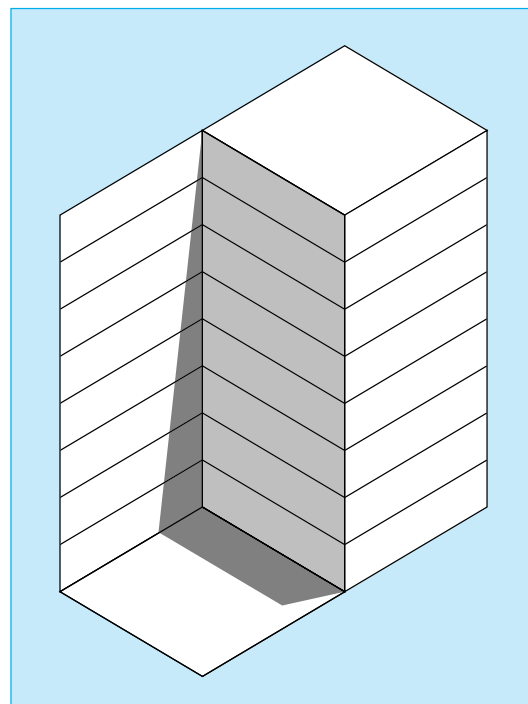
It might be useful to suggest a plan of the cognitive visual system. It is useful to distinguish between top-down knowledge from the past; bottom-up sensory signals from the present; and general rules, such as for perspective, which we may say are introduced sideways (fig 3).

Such a major contribution of stored knowledge to perception is consistent with the recently discovered richness of downgoing pathways in brain anatomy. Some 80% of fibres to the lateral geniculate nucleus relay station come downwards from the cortex, and only about 20% from the retinas.<sup>5</sup> Although the plan of visual processing of figure 3 is not an anatomical

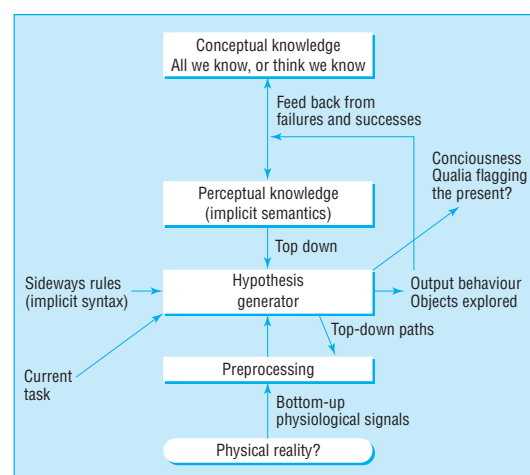
diagram, it is consistent with brain anatomy as currently appreciated.

## Qualia flag the present

We might hazard a guess as to what qualia do. As perception depends on rich knowledge from the past stored in the brain, there must be a problem in identifying the present moment from past memories, and also from anticipations running into the future. The present is signalled by real time stimuli from the senses; but as perceptions are 90% or more stored knowledge, the present moment needs to be identified



**Fig 2** Mach's corner. When the corner flips in depth, the grey region may change quite dramatically in brightness. When the corner is in, it seems lighter than when out. So seemingly simple qualia of consciousness are affected by meanings of perception



**Fig 3** Black box of visual processing. Bottom-up signals from the eyes are read or interpreted with top-down knowledge of objects and with general sideways rules to generate perceptions of the external world. Errors of behaviour with objects feed back to improve perception and motor control through learning

for behaviour to be appropriate to what is happening out there now. When crossing a road, one needs to know that the traffic light seen as red is red now, and not a past remembered red light. This importance of the present is seldom recognised as important by psychologists, though it is discussed by Humphrey.<sup>6</sup>

Try this simple experiment. Look intensely at some distinctively coloured object, such as a red tie. Then close the eyes and imagine the tie. The vivid qualia are suddenly far dimmer in imagination. To reverse the experiment, imagine the object, then open the eyes and look at it. The qualia of the visual are now startlingly vivid by comparison with the memory. So perhaps what qualia do is flag the present so that we do not get confused with remembered past or anticipated future.

## Exceptional cases

At least one exceptional person free of drugs or schizophrenia has been described as confusing memories with present reality. This is the remarkable case of S described by the Russian neuropsychologist Alexander Luria.<sup>7</sup> At times in his strange life S was a professional memory man. His vast memory and extremely vivid imagination became confused with realtime reality to the point of danger. It may be suggestive that he experienced unusually rich synaesthesia.<sup>7</sup> Confusions of memory with present reality could be dangerous for him, as he would confuse imagined with real traffic lights, and as he said: "I'd look at a clock and for a long while continue to see the hands fixed just as they were, and not realise time had passed ... that's why I'm often late."<sup>7</sup>

There are some commonly experienced failures of separating the present from memory. An after-image from a bright flash gives qualia lasting even minutes after the flash. But afferent signals continue after this stimulus (gradual breakdown of photopigment molecules) so, as for normal perception, there is a present afferent input but giving qualia from past stimuli.

Vivid qualia unrelated to present sensory signals seem to be experienced in dreams. In sleep the present moment has no special significance, for behaviour is not related to external events. When sensory inputs are cut off, or ignored, the system may become abnormal. This occurs in isolation situations when sensory stimulation is absent over many hours. And in hallucinogenic drug induced states and in schizophrenia vivid qualia are experienced with no sensory input; but similar brain activity seems to be present.<sup>8-10</sup>

It is reported that in drug induced states time may seem to stop. In *The Doors of Perception* Aldous Huxley describes changes of consciousness experienced with mescaline.<sup>11</sup> He ceases to be interested in action, becoming a passive observer ("the will suffers a profound change for the worse"), though his ability to think straight is little if at all reduced. So he becomes almost "a Not-self." Most suggestive, "Visual impressions are greatly intensified," while "interest in space is diminished and interest in time falls almost to zero." Huxley emphasises that colours are immeasurably enhanced in vividness, ordinary objects appearing self luminous, with the inner fire of jewels, while time essentially stops, becoming "an indefinite duration or alternatively a perpetual present." With mescaline and

other hallucinogenic drugs sensations become enhanced—super qualia—and the present is emphasised with corresponding little flow of time.

Although memories usually lack visual or other qualia, sensations are surprisingly vivid in remembered emotions, as when an embarrassing situation is recalled years later. William James, with the Danish physician Carl Lange, suggested that emotions have a basis in autonomic changes of the body.<sup>12</sup> The James-Lange theory of the emotions is that the body responds—for example, to danger—by preparing for action and these autonomic physiological changes are sensed as emotions, of fear or rage or whatever. For shame there is a marked autonomic change with visible blushing. Darwin suggested that blushing is a social signal, warning others that this person is not to be trusted.<sup>13</sup> It is possible to blush at the memory, or thought, of the shame-making deed—and to experience qualia of shame years after the event—presumably because of the presence of afferent inputs from autonomic bodily changes evoked by memories.

This notion that qualia normally flag the present does not begin to explain how qualia are produced by brain processes; though much has been discovered recently, especially for vision.<sup>14 15</sup> Which brain regions are affected should change with changes of cognitive processing, to be charted dynamically with local changes of blood flow recorded by functional magnetic resonance imaging. These new techniques of brain research are promising deeper understanding of how physiological functions are related to cognitive processing and to consciousness, but much remains mysterious.

This idea of flagging the present has implications for consciousness in other animals. As perception evolved to become more intelligent through evolution, it drew away from direct control by stimuli as it depended increasingly on hypotheses of what might be out there. So identifying what is out there now must have become an increasing problem with development of cognitive brain function.

Intelligence cannot be tied to the sensed present. So here there is a balancing act. What is needed for imagination and intelligence is what pushes the mind to distance present reality. It is a speculation that qualia normally flag the present. But, as the tortoise said, "I can't take a step forward without sticking my neck out."

- 1 Gregory RL. Perceptions as hypotheses. *Philosophical Transactions of the Royal Society of London* 1980;290 (series B):181-97.
- 2 Gregory RL. *Mind in science*. London: Weidenfeld and Nicolson, 1981.
- 3 Gregory RL. Knowledge in perception and illusion. *Philosophical Transactions of the Royal Society of London B* 1997;352:1121-8.
- 4 Mach E. *Analysis of sensation* (translated by S Waterlow). New York: Dover, 1959.
- 5 Sillito A. Chemical soup: where and how drugs may influence visual perception. In: *The artful eye*. Oxford: Oxford University Press, 1995:294-306.
- 6 Humphrey N. *A history of the mind*. New York: Simon and Schuster, 1992.
- 7 Luria A. *The mind of a mnemonist: a little book about a vast memory*. New York: Cape, 1969.
- 8 Kosslyn SM, Thompson WL, Kim IJ, Alpert NM. Topographical representations of mental images in primary visual cortex. *Nature* 1995;378:496-8.
- 9 Silbersweig DA, Stern E, Frith C, Cahill C, Holmes A, Grootenk S, et al. A functional neuroanatomy of hallucinations in schizophrenia. *Nature* 1995;378:176-9.
- 10 Posner MI, Raichle ME. *Images of mind*. New York: Freeman, 1994.
- 11 Huxley A. *The complete works of Aldous Huxley*. London: Chatto and Windus, 1968.
- 12 James W. *Principles of psychology*. London: Macmillan, 1890.
- 13 Darwin CR. *Expression of the emotions in man and animals*. London: John Murray, 1872.
- 14 Zeki S. *Vision and the brain*. Oxford: Blackwell Scientific, 1993.
- 15 Crick FC. *The astonishing hypothesis*. New York: Scribners, 1994.